Feeding Behavior of Juvenile *Notothenia rossii marmorata* FISCHER at South Georgia Station

Takao HOSHIAI*

ウミタカスズキ (*Notothenia rossii marmorata* FISCHER) 幼魚の摂餌行動

星　合　孝　男*

要旨: 1973年1月末，サウスジョージアにあるイギリス観測隊の基地で，ウミタカスズキ幼魚の摂餌行動を観察した．

常には底生生活を営み，底生生物を摂取しているウミタカスズキ幼魚が，夜間，桟橋の照明に集った大型動物プランクトンをねらって水面直下にまで浮上し，泳ぎ回っている動物を捕食するのを観察した．

胃内には幽門部から噴門部へかけて，エビの1種 *Chorismus antarcticus* と端脚類，多毛類の1種 *Neanthes kerguelensis* の遊泳生殖個体，ウミタカスズキならびに Bathydraconidae sp. を主とした稚魚が，それぞれ団塊となって詰っていた．胃内容物とプランクトン相とを比較したところ，ウミタカスズキ幼魚は，プランクトン動物の中から，より大型な動物を選択的に捕食したものと考えられた．また，幼魚が捕食する対象は，ある程度の大きさであると同時に，魚の目の前で動くことが必要であるらしく思われた。

このような行動を示した魚の胃内容物は，底に止っている個体の胃内容物とは異なったものであった。

Abstract: The feeding behavior of juveniles of *Notothenia rossii marmorata* was investigated by the examination of stomach contents of three fish and by the field observation. Juvenile *Notothenia* came to the lighted area of shallow beach and fed on the swimming animals attracted by the light in late January of 1973. Amphipods, *Chorismus*, *Neanthes* and fish fry were mainly eaten in this order from evening to midnight. Juvenile *N. rossii marmorata* preferred the largest or larger animals in a prey population.

Stomach contents of 64 juveniles of bottom dwelling *N. rossii marmorata* were also examined. Gammarid amphipods, algae and Ctenophore occurred frequently in the stomachs. The juvenile fish captured not only swimming animals but also swaying algae and Ctenophore.

1. Introduction

The study of stomach contents of fish is one of the effective means for the

* 国立極地研究所. National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173.

analysis of the trophic organization in a marine ecosystem. Several investigations on the diet of fishes were carried out in the Southern Ocean (DEWITT and HOPKINS, 1977; HUREAU, 1970; KAWAMURA, 1976; KEYSNER *et al.*, 1974; PERMITIN, 1970; PERMITIN and TARVERDIYEVA, 1972, 1978; TARVERDIYEVA, 1972). However, majority of fishes examined by these authors were collected by the works on board, and there are few records on the feeding behavior in their habitats.

The present author, as the Japanese exchange scientist in accordance with Article III of the Antarctic Treaty, had an opportunity to stay at South Georgia Station of the United Kingdom between 17 January and 3 March 1973. By accident, he found out juveniles of *Notothenia rossii marmorata* FISCHER swimming around to take food at the beach near the jetty of the Station on the night of 23 January. Immediately, the observations of the feeding behavior of the fish were commenced and the related studies were also conducted.

Although the results obtained through the present investigations are fragmentary and the processing of samples collected is still incomplete, they are outlined in the present report, because they seem to offer suggestions for the understanding of the previous works on the stomach analysis of this species and other Antarctic and Subantarctic species.

2. Materials and Methods

As mentioned above, juvenile fish were discovered at the shallow beach of a few meters in depth, which is close to the landward edge of the jetty and also in front of the base commander's office. A mercury-vapor lamp was installed to illuminate the jetty and its adjoining beach. Juveniles of *Notothenia* swam around just beneath the water surface in the lighted area to search for food and frequently swallowed them with a splash. It looked like that the fish fed selectively on a certain prey.

Five fish were scooped up with a small square dip-net which is a popular and ordinary net for tropical fish cultivation. The stomach contents of three fish out of five were examined, and one stomach which was removed from fish and one fish were preserved for studies expected in the future.

A comparison of the species composition of stomach contents with that of the prey organisms in the surrounding sea water was made for the examination of the food preference of juvenile *Notothenia*. Since the prey population consisted of the swimming animals which appeared to be attracted by the light of the mercury-vapor lamp, they were captured with the same dip-net as mentioned above.

In order to know the diet items of the bottom dwelling individuals of juvenile *Notothenia*, the stomach contents of fish caught by a seine net which was set at the mouth of King Edward Cove were also investigated. The fish collection with the seine net was performed by the British Antarctic Survey biologists for the purpose of sampling otolith of fishes. After removing the otolith, stomachs of *Notothenia* were kindly offered to the author for the present investigation.

3. Results and Discussion

The length and weight of five individuals collected are given in Table 1 with the weight of stomachs. All of stomachs of five fish were full. The components

Table 1. Data on examined individuals of Notothenia rossii marmorata.

Individuals	Time	Total length (cm)	Wet weight (g)	Stomach weight (g)	Remarks
No. 1	2300 23 Jan. 73	25.7	280	70	Removed stomach preserved
No. 2	2300 23 Jan. 73	30.0	380	90	
No. 3	2400 23 Jan. 73	28.2	400	70	
No. 4	2300 23 Jan. 73	28.7	300	—	Preserved
No. 5	2400 29 Jan. 73	33.5	480	70	

Table 2. Stomach contents of juveniles of Notothenia rossii marmorata.

Fish	No. 2		No. 3		No. 5	
Stomach contents	Individ. No.	%	Individ. No.	%	Individ. No.	%
Notothenia rossii marmorata	157	36.77	139	21.45	1	0.12
Bathydraconidae sp.	4	0.94	7	1.08	483	60.30
Neanthes kerguelensis	34	7.69	104	16.07	29	3.62
Chorismus antarcticus	80	18.74	352	54.40	13	1.62
Parathemisto gaudichaudii	31	7.26	20	3.15	170	21.22
Hyperoche sp.	5	1.17	3	0.45	1	0.12
Hyperiella sp.	36	8.43			20	2.50
Hyperia sp.					5	0.62
Gammarid amphipods	78	18.27	21	3.20	78	9.74
Total of amphipods	150	35.13	44	6.80	274	34.21
Isopod			1	0.15		
Euphausia larvae	2	0.47			1	0.12
Total individ. numbers	427		647		801	

of stomach contents and the percentage of individual numbers of each component to the total are listed up in Table 2. Eleven items were distinguished from three stomachs and seven were common to the three. Fry of two kinds of fish, *Notothenia rossii marmorata* and Bathydraconidae sp., amphipods composed of hyperiids and gammarids, a shrimp, *Chorismus antarcticus* and epitokous of a nereid worm, *Neanthes kerguelensis* were the main food items. However, the relative abundance of the component species in three stomachs differed from one another. The difference between No. 2 fish and No. 3 seemed to depend upon the difference of individual variation in feeding behavior but that between the fish caught on 23 January and the fish of 29 January seemed to be derived from the difference in composition of prey species in the sea water.

Diet components in a stomach were arranged in the specific order as shown in Fig. 1. When a part of stomach wall of No. 2 fish was removed, it was seen that *Ch. antarcticus* occupied the pyloric part with amphipods and fry of *Notothenia* filled the oesophagal orific area. *Ne. kerguelensis* was situated between the *Chorismus* portion and the fish fry mass. The diets of No. 5 fish were also arranged in the order of digested crustaceans with two colonies of hydrozoans, *Ne. kerguelensis* and fry of Bathydraconidae sp. from pyloric to oesophagal orific area (Fig. 1).

The arrangement of prey species ingested suggested either the species composition of prey organisms in the surrounding sea water or the food preference of *Notothenia* changed with the lapse of time. Figs. 2 and 3 show the results of two series of successive samplings of swimming animals in the sea. Copepods were always collected but they were not dealt with here, because no copepods were found in the stomachs. One serial sampling was carried out on the night of 31

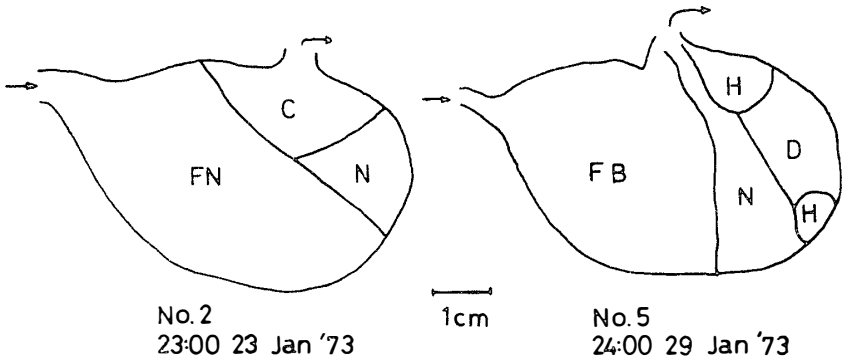

Fig. 1. Arrangement of diet components in the stomachs of Notothenia rossii marmorata.
FN: Fry of Notothenia rossii marmorata *FB: Fry of Bathydraconidae sp.*
C: Chorismus antarcticus *H: Hydrozoa*
N: Neanthes kerguelensis *D: digested crustaceans*

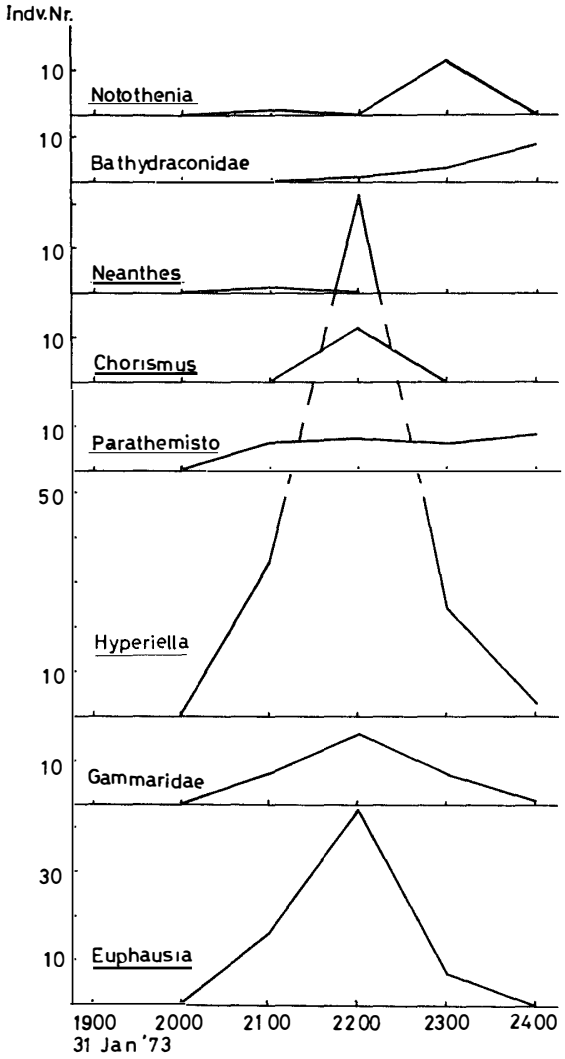

Fig. 2. Successive change of the swimming animal population at the beach in front of the base commander's office of South Georgia Station.

January. Before 21:00 only copepods were obtained. Between 20:00 and 21:00 it became dark and juveniles of *Notothenia* began to appear. At 21:00, amphipods occurred with *Euphausia* larvae, *Neanthes* and a few fry of *Notothenia*. The dominancy of crustaceans continued till 22:00. Fry of *Notothenia* appeared at 23:00 and fry of Bathydraconidae sp. which appeared at 22:00 increased in number from 23:00 to 24:00. This successive change in the individual numbers of swimming animals in the sea corresponds to the position of crustaceans and of fish fry in the stomachs of No. 2 and No. 5 fish. It is also suggestive to explain the position of *Neanthes* in the stomachs that its epitokous were found only in the evening.

On the night of 23 January, the swimming animals were sampled twice at 23:00 and 24:00. In the sample collected at 23:00, *Chorismus* and amphipods

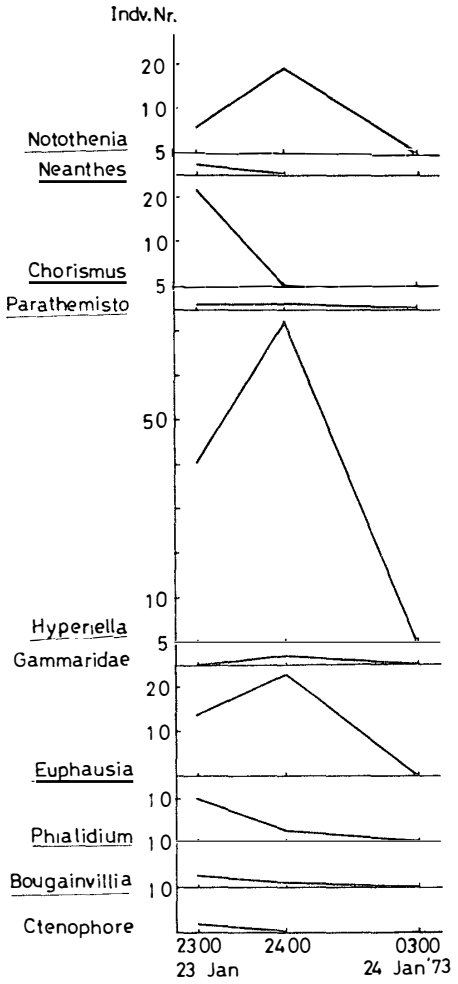

Fig. 3. Successive change of the swimming animal population at the beach in front of the base commander's office of South Georgia Station.

were prominent and two kinds of medusa, *Phialidium simplex* and *Bougainvillia macroviana* and Ctenophore were found. At 24:00, the swimming animal population was composed mainly of fry of *Notothenia*, amphipods and *Euphausia* larvae. The third sampling was done at 03:00 in the early morning of 24 January, when it was dawn and no juvenile *Notothenia* were found to swim. Only a few copepods were collected at that time. The order in occurrence of swimming animals in the sea as mentioned above coincides with the order of diet components arrangement from the pyloric to the oesophagal orific area in the stomach of No. 2 fish except that no medusae and Ctenophore were found in the stomach.

An exact comparison is possible between the species composition of the swimming animal population in the sea water and that of the diet in the oesophagal orific part of stomach of the fish caught concurrently at 23:00 of 23 January. It

Table 3. Species composition of fish stomach content and of prey population in the sea caught concurrently at 23:00, 23 January 1973.

Species	Prey in the sea		Stomach content of fish	
	Individ. No.	%	Individ. No.	%
Notothenia rossii marmorata	6	5.71	152	74.88
Bathydraconidae sp.			2	0.98
Neanthes kerguelensis	2	1.90		
Chorismus antarcticus	22	20.95	5	2.46
Parathemisto gaudichaudii	1	0.95	15	7.39
Hyperoche sp.			5	2.46
Hyperiella sp.	40	38.10	12	5.91
Gammarid amphipods			7	3.45
Euphausia larvae	14	13.33	1	0.49
Pteropods	5	4.76		
Phialidium simplex	10	9.52		
Bougainvillia macroviata	3	2.86		
Ctenophores	2	1.90		

Table 4. Body length with standard deviation of main diet components.

Species	Length (cm)
Notothenia rossii marmorata	3.43±0.19
Bathydraconidae sp.	2.55±0.18
Trematomus sp.	0.99±0.07
Neanthes kerguelensis	3.23±0.31
Chorismus antarcticus	1.55±0.04
Parathemisto gaudichaudii	1.49±0.19
Hyperiella sp.	0.81±0.11
Euphausia larva	0.72±0.16

became clear from the comparison that the relative abundance of species ingested differed from that of swimming species in the sea. As shown in Table 3, the numerically prominent species were *Hyperiella* sp., *Ch. antarcticus* and *Euphausia* larva but fry of *Notothenia* was the fifth component in the sea. However, the most remarkable species in the stomach was the fish fry and percentages of the crustacean species were low. Particularly it was interesting that only one *Euphausia* larva was found. Therefore, it seemed that juvenile *Notothenia* prefers fish fry when they are available as its food. When there were no or few fish fry in the prey

Table 5. Species composition in three portions distinguished by the representative diet components, fry of Notothenia rossii marmorata *(FN),* Ne. kerguelensis *(N) and* Ch. antarcticus *(C) in the stomach of No. 2 fish.*

Diet components	FN		N		C	
	Individ. No.	%	Individ. No.	%	Individ. No.	%
Notothenia rossii marmorata	152	74.88	3	4.41	2	1.28
Bathydraconidae sp.	2	0.98	1	1.47	1	0.64
Neanthes kerguelensis	4	1.97	24	35.29	6	3.85
Chorismus antarcticus	5	2.46	1	1.47	74	47.44
Parathemisto gaudichaudii	15	7.39	10	14.71	6	3.85
Hyperoche sp.	5	2.46				
Hyperiella sp.	12	5.91	16	23.53	8	5.13
Hyperia sp.	7	3.45	13	19.12	58	37.18
Gammarid amphipods						
Total of amphipods	39	19.21	39	57.35	72	46.15
Isopod						
Euphausia larvae	1	0.49			1	0.68
Total individ. numbers	203		68		156	

Table 6. Species composition in three portions distinguished by the representative diet components, fry of Bathydraconidae sp. (FB), Ne. kerguelensis *(N) and digested crustaceans (D) in the stomach of No. 5 fish.*

Diet component	FB		N		D	
	Individ. No.	%	Individ. No.	%	Individ. No.	%
Notothenia rossii marmorata	1	0.15				
Bathydraconidae sp.	471	74.64	10	9.26	2	3.23
Neanthes kerguelensis			26	24.07	3	4.84
Chorismus antarcticus	3	0.48	4	3.70	6	9.68
Parathemisto gaudichaudii	95	15.06	39	36.11	36	58.06
Hyperoche sp.	1	0.15				
Hyperiella sp.	11	1.73	1	0.93	8	12.90
Hyperia sp.	43	6.81	28	25.93	7	11.29
Gammarid amphipods	5	0.79				
Total of amphipods	155	24.56	68	62.97	51	82.25
Euphausia larvae	1					
Total individ. numbers	631		108		62	

population, juvenile *Notothenia* preferes alternative prey species, generally the largest or larger species among the swimming animals. From Figs. 2 and 3, it may be said that in general amphipods, *Chorismus*, *Neanthes* and fish fry appear in the lighted sea area in this order. As given in Table 4, they can become the largest or larger component in the swimming animal population at respective occasions of sampling. The results of diet analysis in three portions distinguished by prominent species in two stomachs of Fig. 1 show that juvenile *Notothenia* preferred *Chorismus* or amphipods in the evening and successively ate *Neanthes* before the appearance of fish fry (Tables 5 and 6). However, percentage of ingested amphipods decreased after the appearance of fish fry, although individual numbers of amphipods decreased but were higher than fish fry. Considerable number of *Euphausia* larvae were always found in the sea, but few of them appeared in the stomachs. It appeared that the fish preferentially took prey that were large and moving. This supports the fact that no medusae and Ctenophore were found in the stomachs of fish which fed on the swimming animals.

Notothenia's preference for larger animals in the swimming animal population contributes to the effective acquisition of energy to live. Table 7 shows the weight of diet components in three stomachs. Superiority of fish fry in weight to that in numerical composition is remarkable.

It is considered that the juveniles of *N. rossii marmorata* are benthic and have few opportunities to encounter such aggregations of the prey species as observed before. Therefore, stomach contents of bottom dwelling individuals caught with the seine net were examined. Stomach contents of 64 fish caught on 20 and 21 February 1973 were studied. As shown in Table 8, the diet components of these fish differed from those of fish at the beach. Algae, amphipods and Ctenophore occurred in high percentages among the 14 diet components. From the fact observed

Table 7. Weight of diet components in three stomachs; (gr).

Fish		No. 2			No. 3			No. 5		
Prey specis	Mean weight (g)	Individ. No.	Weight (g)	%	Individ. No.	Weight (g)	%	Individ. No.	Weight (g)	%
Notothenia rossii marmorata	0.22	157	34.54	75.38	139	30.58	55.71	1	0.22	0.64
Bathydraconidae sp.	0.05	4	0.08	0.17	7	0.35	0.63	483	24.15	70.61
Neanthes kerguelensis	0.15	34	5.10	11.13	104	15.60	28.42	29	4.35	12.72
Chorismus antarcticus	0.02	80	1.60	3.49	352	7.04	12.83	13	0.26	0.76
Amphipods	0.03	150	4.50	9.82	44	1.32	2.40	274	5.22	15.26

Table 8. Stomach contents of juvenile Notothenia rossii marmorata *caught by a seine net. Relative abundance of stomach contents of the "light" caught fish are shown by the symbols* ⫲, ⫲, +.

Diet components	Frequency occurrence of a particular component	Percentage of frequency occurrence to the total, 64 individuals	Stomach contents of the "light" caught fish
Fish fry			⫲
Hyperid amphipods			⫲
Gammarid amphipods	35	54.69	⫲
Algae	30	46.88	
Hydrozoans			+
Ctenophore	17	26.56	
Euphausiid	6	6.25	+
Copepods	6	6.25	
Shrimp	5	7.81	⫲
Annelids	3	4.69	
Neanthes kerguelensis			⫲
Cumaceans	3	4.69	
Ostracods	3	4.69	
Gastropods	3	4.69	
Mysids	2	3.13	
Isopods	1	1.56	
Ascidian	1	1.56	
Empty	4	6.25	

at the beach that a juvenile *Notothenia* swallowed a piece of alga which swayed in front of its snout by the wave action, it is supposed that the algae in the stomachs of bottom dwelling *Notothenia* may be ingested in the same way. Majority of amphipods found in stomachs were gammarid amphipods which could cling to algae. Not only algae but also Ctenophore which were found in the stomachs of the bottom dwelling fish were also preferred among the slowly moving objects near bottom.

OLSEN (1954) reported that juveniles of *N. rossii marmorata* fed on benthic crustaceans and took small fish when possible. The present observation gave more detailed information on the actual feeding behavior to interpret his conclusive and short comments. The diet components of juveniles of *N. rossii marmorata* resemble those of *N. rossii rossii* reported by HUREAU (1970). The frequency of occurrence of fish, algae and benthic crustaceans is high. This fact seems to support the prospect that the feeding behavior observed at South Georgia is not an exceptional one.

It is well known that Ctenophore, hyperiid amphipods, euphausiids and salps are in the diets of adult *N. rossii marmorata* and the importance of krill, *Euphausia superba* as the prey is emphasized. PERMITIN (1970) mentioned feeding of *N. rossii marmorata* in the krill swarm. The same behavior as observed at the beach of South Georgia is expected in the off-shore area. Stomach contents of this species may vary depending upon the species composition of prey population around it.

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